Aspects of the Desiccation Tolerance of Four Species of Benthic Mollusca from Plover Cove Reservoir, Hong Kong

BY

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(1 Text figure)

INTRODUCTION

Water level fluctuations are a common feature of man-made lakes and may lead to the stranding of large numbers of macroinvertebrates on the exposed shores of such habitats (McLachlan, 1969; 1970a; Kaster & Jacobi, 1978; Marshall, 1978). In certain taxa, such as the Chironomidae (Diptera) (McLachlan, 1970a & b), the loss of biomass is almost immediately made up by reproduction. However, in species with a restricted breeding period any ability to survive dry conditions until the waters of the habitat return to their former levels would be of considerable selective advantage. It would be expected that freshwater taxa living in tropical climates would possess this capacity, particularly those lacking the vagility of insect populations, for the seasonal nature of precipitation in such regions enhances the likelihood of natural habitats drying out after a prolonged period without rain (*e.g.*, McLachlan & McLachlan, 1969).

Tolerance to desiccation is a capacity shared by a variety of taxa ranging from insects and molluscs (Coles, 1969a; Beadle, 1974; Stiglingh & van Eeden, 1977) to vertebrates (*e.g.*, the lung fish *Protopterus*). Such resistance is termed aestivation and involves a reduction in metabolic rate and the production of a structure which reduces the rate of water loss, such as the "cocoon" of lung fish and the epiphragm (of mucus or calcified mucus) formed over the mouth of the shell of pulmonate gastropods (W.H.O., 1968; Stiglingh & van Eeden, 1977). A form of aestivation has been noted in certain species of ostracods which can survive in the absence of water in a "torpid" adult stage (McClay, 1978). The process of aestivation is distinct from cryptobiosis which involves survival during dry conditions in a state of complete dehydration (Beadle, 1974) as seen in the drought resistant egg stages of some freshwater Microcrustacea (Rzoska, 1961) and insect larvae (Hinton, 1960a & b) which inhabit temporary freshwater pools in tropical regions.

The following investigation is concerned with the tolerance to desiccation of four species of Mollusca found stranded on a gently sloping marginal zone of Plover Cove Reservoir, Hong Kong, after a fall in water level during 1978. It was hoped to determine whether subsequent recolonization of the marginal zone was from dormant individuals or solely as a result of animals migrating into the newly flooded habitat.

MATERIALS and METHODS

Four species of Mollusca, *Sinotaia quadrata* (Benson, 1842) (Gastropoda: Prosobranchia: Viviparidae), *Thiara scabra* (Müller, 1774) and *Melanoides tuberculata* (Müller, 1774) (Gastropoda: Prosobranchia: Thiaridae), and *Corbicula fluminea* (Müller, 1774) (Bivalvia: Corbiculacea: Corbiculidae), were employed in the present investigation. These animals comprised the dominant elements of the benthic fauna of Plover Cove Reservoir and were collected using an Agassiz trawl operated from a boat. Test animals were maintained in aerated laboratory tanks prior to experimentation so as to ensure that only healthy specimens were used. The effect of aerial exposure in the absence of mud (which is normally present in much of the habitat of the species investigated) was tested by putting large groups of the test animals into dry enamel trays at room temperature (24°-26° C) and relative humidity

varying between 60 and 70%. Five individuals of each species were removed every day and placed in shallow dishes of water. The number of animals which had revived after 24 hours was counted and expressed as a percentage of the total removed. The experiment continued until all of the animals were killed. The effect of mud on the survival of the molluscs was investigated by placing large enamel trays containing blocks of reservoir mud into the laboratory tanks where the three species of snails were maintained. The animals were allowed to wander freely over the substrate. In the case of the bivalve, *Corbicula fluminea,* a number of individuals were put on the surface of mud blocks in enamel trays in the maintenance tanks and left undisturbed for five days, after which time they had buried themselves. All of the trays were then removed from the tanks. Gutters were cut in the mud around the margins of the trays and all of the free water was siphoned out. This was considered to represent the start of the exposure period and further procedure followed that outlined above for animals in bare trays. All test animals were washed clean of mud before the capacity for revival was determined.

The effect of size on the ability of *Corbicula fluminea* to withstand aerial desiccation in the presence and absence of mud was examined with experimental animals being divided into two groups: those less than 10 mm in length (small) and those greater than 10 mm in length (large).

RESULTS

The effects of aerial desiccation on benthic molluscs from Plover Cove Reservoir were altered according to the test species concerned and the presence or absence of reservoir mud. Survival of *Melanoides tuberculata* and *Thiara scabra* was enhanced in the presence of mud. *Thiara scabra* was more susceptible to desiccation, living for only three days in a bare dry pan, but up to two weeks in the presence of mud. In *M. tuberculata* length of survival was 8 days and 24 days, respectively, for these treatments. A similar enhancement of survival in the presence of mud was noted for *Sinotaia quadrata,* test animals surviving for 32 days in such situations as compared to 20 days in bare trays. However the effect of mud on the survival of this species was relatively less than that recorded for *M. tuberculata* or *T. scabra,* although *S. quadrata* tolerated desiccation for longer than the former species.

Although only large individuals of the three species of gastropod were used in these experiments, in the case of *Corbicula fluminea* the test animals were divided into large and small size groups. In bare pans the smaller individuals had all died by the fourth day, while larger animals survived for 9 days. In the presence of mud the survival of both groups was enhanced, smaller animals living for 6 days and larger animals surviving until the twelfth day. These findings are summarized in Figure 1.

DISCUSSION

The inundation of a previously exposed portion of a gently sloping marginal zone of Plover Cove Reservoir, Hong Kong, produced an interesting pattern of faunal recolonization initially dominated by the gastropod *Melanoides tuberculata* (Dudgeon, in prep.). While investigations of the stranded fauna indicated that (in 1978) all of these animals had died, thereby suggesting that recolonization of the marginal zone upon inundation would be due to immigration, no information on the ability of the reservoir benthos to survive aerial exposure was available. The present study was intended to contribute to knowledge in this area.

Tolerance to desiccation was markedly altered by size. In the absence of free water, large individuals of *Corbicula fluminea* survived for approximately 30 per cent longer than smaller ones. Although the presence of mud enhanced survival in both groups, this differential was maintained. Similar size related tolerance to desiccation has been recorded in marine (Coombs, 1973) and freshwater molluscs (Harris & Charleston, 1977; Stiglingh & Van Eeden, 1977). This phenomenon may be associated with alterations in tissue water content or shell shape during growth. However the shell shape of *C. fluminea,* whilst rather variable (Hayashi, 1956; Sinclair, 1971), does not alter significantly during postembryonic development. Changes in surface to volume ratio as these animals increase in size may render larger individuals less susceptible to water loss, and due to their higher metabolic rate (Dudgeon, 1980) smaller animals would suffer from respiratory stress sooner after closing the shell valves to avoid desiccation than would larger ones; *C. fluminea* has no obvious adaptations to desiccation such as those found in the unionid bivalve *Asparthia* sp. which can aestivate for up to two years (Beadle, 1974), or the mangrove corbiculid *Polymesoda (Geloina) erosa* which can survive out of water for over a month (Dr. B. Morton, personal communication). Indeed, the test species is comparable with *Lasmigona complanata* (Unioninae) which only survives for five days after exposure to the air (Kaster & Jacobi, 1978). A recent study of the desiccation tolerance of *C. fluminea* undertaken in North America (McMahon, 1979) also records

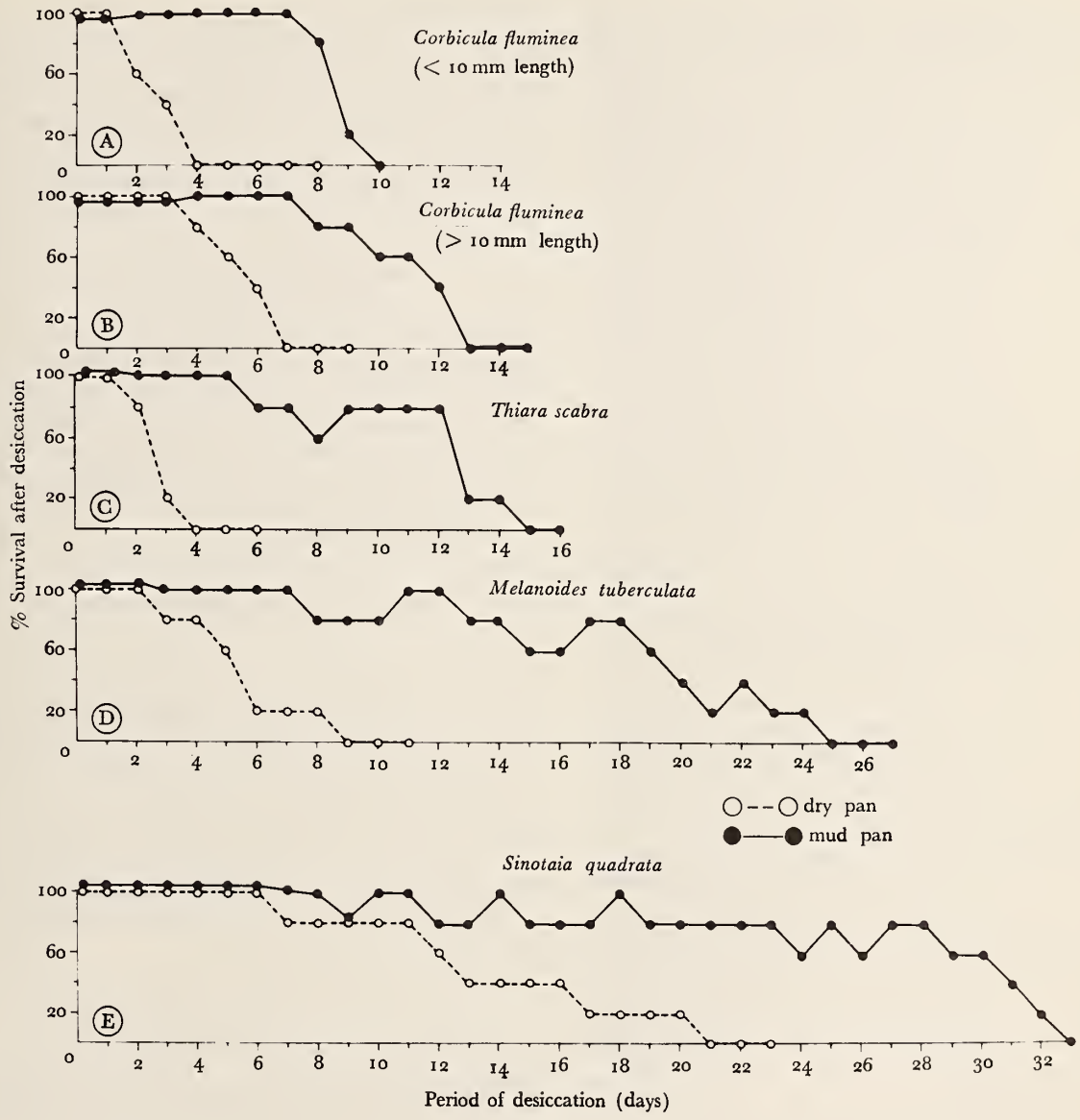

Figure 1

Graphs showing the survival of four species of Mollusca from Plover Cove Reservoir, Hong Kong, in conditions of aerial exposure in the presence or absence of mud substrate

that this species is relatively intolerant of aerial exposure, and postulates that in damp air accumulation of metabolites is the main cause of death, whilst desiccation is a more important source of fatalities in low humidities. As mud is likely to increase the relative humidity in the microhabitat immediately surrounding stranded animals, it is possible that death in the presence of mud is due to the former cause with fatalities on the bare trays occurring as a result of desiccation. Further studies are required to elucidate these points.

Water loss through the shell is thought to be of minor significance in gastropods (Cameron, 1970), and it is

probable that both in prosobranchs and pulmonates drying out of the peripheral tissues around the mouth of the shell occurs early in desiccation, thus slowing the rate of water loss. The response of test gastropods to the presence of mud generally resulted in the snails coming to rest with the aperture buried in the soft substrate. This greatly enhanced the survival of *Melanoides tuberculata* and *Thiara scabra* but to a much lesser degree in *Sinotaia quadrata*. Since the latter species had the longest survival time of all the species tested on bare trays, and the presence of mud, which appears to reduce water loss through the operculum of the other test snails, had a comparatively small effect on the duration of survival, it is probable that the operculum of *S. quadrata* is more impermeable to water loss than that of *T. scabra* or *M. tuberculata*. An inability to respire anaerobically for an extended period of time may thus be more important than water loss in limiting the length of time that *S. quadrata* can withstand desiccation.

The action of mud in enhancing the survival of stranded molluscs may have been due to a reduction in water loss from wholly or partially buried individuals in comparison with those animals exposed on bare trays. Aestivation of gastropods in crevices in mud is known to increase the likelihood of survival in dry conditions, as these localities have humidities which are higher and temperatures which are lower than exposed sites; hence, the rate of evaporative loss is reduced (Machin, 1975). Behaviour which leads to a partial or complete covering by mud can also help stranded animals to avoid lethal day-time temperatures and this was probably of particular significance on the shores of Plover Cove Reservoir where there was no shade from the direct sunlight. Indeed some gastropods are stimulated to bury in response to the onset of dry conditions, thereby increasing their chances of survival (Machin, *op. cit.*). Apparently, mud provides a damp microhabitat for aestivation as well as partially sealing those openings (shell valves and apertures) through which water loss can occur.

The maximum periods of survival of the species in the present investigation ranged between 9 and 31 days and they would have been unable to survive the 2½ month period of exposure of the marginal zone of Plover Cove Reservoir during early 1978. This was confirmed by observations of stranded animals in the field. Thus, in comparison to certain pulmonate gastropods such as the Planorbidae (*Biomphalaria* spp.) (W.H.O., 1968) and the Bulininae (Stiglingh & Van Eeden, 1977), as well as some prosobranchs (*e.g., Pila ovata,* Coles, 1969a & b), the species tested had a limited capacity for aestivation. It may be significant that those molluscs with the greatest capacity to survive periods without water are those which inhabit temporary freshwater bodies. In fact, there appears to be a correlation between the ability to survive desiccation and the permanence of the usual habitat of the species under consideration (Machin, 1975). This generalization is supported by the results of the present study as *Melanoides tuberculata* and *Sinotaia quadrata,* which have relatively good tolerances of dry conditions, are frequently found in irrigation ditches, paddy fields and wet vegetable plots in Hong Kong: habitats with a restricted degree of permanence. In contrast, *Thiara scabra* is the dominant element of the macrofauna on steeply sloping rocky shores in Plover Cove Reservoir (Dudgeon, in press). In such situations a fall in water level exposes only a small area of the shoreline and thus reduces the chances of these snails being stranded. Similarly, *Corbicula fluminea* would not be expected to show a marked ability to survive desiccation, as its natural habitat in Hong Kong is permanently flowing streams and rivers.

The present study indicates that planned drainage and drawdowns of molluscan habitats, as has sometimes been employed as a means of controlling disease vectors (Jobin, 1970), could be a viable method of reducing the populations of a variety of pest species. *Corbicula fluminea* has become a severe nuisance in waterways in the United States (Prokopovitch, 1969; McMahon, 1977) and *Melanoides tuberculata* serves as an intermediate host of certain parasitic trematodes (Meakins & Kawooya, 1973), as do some other thiarids (*e.g.,* Hamajima *et al.,* 1976). On the basis of the poor capacity for survival shown by the test species in the absence of water, it would appear that drainage of the habitats of these molluscs in areas where they, or related taxa, have become pests could be a good basis for control measures.

SUMMARY

A study of the ability of four species of benthic Mollusca from Plover Cove Reservoir, Hong Kong, to withstand desiccation was undertaken. The test species were the bivalve *Corbicula fluminea* and the gastropods *Thiara scabra, Melanoides tuberculata* and *Sinotaia quadrata.* Large individuals of *C. fluminea* withstood aerial desiccation much better than smaller ones and allowing the animals to bury themselves in mud prior to desiccation increased survival time in this species. The presence of mud also improved the tolerance to desiccation in the three species of test gastropods. In order of increasing ability to withstand aerial exposure the experimental populations were ranked as follows: small *C. fluminea,* large *C. fluminea, T. scabra, M. tuberculata* and *S. quadrata.*

The results were discussed with reference to what is known of the biology of these species in Hong Kong and available information concerning molluscs in other regions. It is concluded that aestivating individuals of the test species would not be significant colonizers of the marginal zone of Plover Cove Reservoir when it was flooded in the summer of 1978 following a 2½ month period of aerial exposure and desiccation.

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